Master internship 2021 in Lyon, France

Artificial Intelligence and Monte Carlo simulations for medical physics and nuclear medicine: investigating GAN for SPECT/PET imaging simulations

https://www.creatis.insa-lyon.fr/site7/en/node/47033

This work is a collaboration between researchers from CREATIS lab and the nuclear medicine department of the Léon Bérard cancer center (Lyon, France). Funded by the Labex PRIMES.

Scientific context. Monte Carlo simulations of nuclear-based imaging systems (SPECT, PET, Compton Camera) are a key tool to investigate and optimize the experimental design of such systems and to carry out research in image reconstruction. It is used by industrials and researchers all over the world. However, Monte Carlo requires a lot of computation time, in particular for the simulation of SPECT and PET imaging systems.

Recently, our group proposed [1] the use of AI methods to replace large and inconvenient phase space files used in Monte Carlo simulations by a compact generative adversarial network (GAN). GAN models the probability distribution of particles in the phase space and is used as a source of particles. This first attempt was efficient but rose a number of theoretical and practical questions, such as: how to optimize the size of the learning dataset? What are the statistical properties of the particles generated by the GAN? In the mentioned work, GAN was applied for medical linear accelerator beam modelling. Here, we intent to investigate the use of GAN for imaging simulations of SPECT systems. Is it possible to learn a GAN that will generate all particles outgoing the imaged patient (or phantom)?

Medical context. In nuclear medicine during last ten years, cancer treatment by Molecular Radionuclide Therapy (MRT) has been growing rapidly. As an example, peptide receptor radionuclide therapy (PRRT) has been shown to be an alternative treatment for neuroendocrine tumors (NETs) when surgery is not indicated [3]. MRT consists in intravenous administration of a molecular vector labeled with a radionuclide. The vector's goal is to accumulate the compound in target organs and the β or α-emitting radionuclide provides cytotoxic effects. Lutetium 177 is one of the most used radionuclides. In addition to β particles, it also emits γ rays that allow to quantify the radionuclide concentration in the tumors and healthy organs with SPECT/CT image acquisitions repeated at different point-times after treatment injection. By estimating the biodistribution and the pharmacokinetic of the activity inside the patient from SPECT/CT images a personalized dosimetry can be performed. Patient-personalized dosimetry [4], [5] is a key notion that allows to optimize tumor control by administering the highest possible activity in target volume while limiting irradiation complications to organs at risk. This image-based dosimetry estimation is however impaired by numerous effects (attenuation, scatter, breathing motion…) that must be corrected or accounted for [6]–[8]. Accurate Monte Carlo simulation of SPECT imaging systems [9], [10] allows to optimize the acquisition parameters, to calibrate the images and to estimate the dose distribution.

Objectives of the master internship.

1. Perform bibliographic review of GAN concept, with application to Monte Carlo simulations.
2. Investigate statistical properties of GAN-based learnt phase-spaces.
3. Investigate the optimization process (loss function, learning rate, etc) of GAN.

Important note:
this master internship may be followed by a **PhD funded position**, starting Sept 2021.

Environment. The student will work in a multidisciplinary team composed of nuclear physicians, medical physicists, researchers and computer scientists of CREATIS laboratory and Leon-Bérard Cancer Center.

Expected skills and other information

- Expected skills: AI, medical physics, computer sciences, image processing
- Technical skills: PyTorch, Python, C++ (Geant4, Gate)
- English and French
- Expected start: 2021
- Location: Lyon, Léon Bérard Cancer Center, France
- Send CV to: david.sarrut@creatis.insa-lyon.fr and ane.etxebeste@creatis.insa-lyon.fr

References

[1] D. Sarrut, N. Krah, and J.-M. Letang, "Generative adversarial networks (GAN) for compact beam source modelling in Monte Carlo simulations," *Phys. Med. Biol.*, Aug. 2019, doi: 10/gf82xv.

[2] D. Sarrut, N. Krah, J. N. Badel, and J. M. Létang, "Learning SPECT detector angular response function with neural network for accelerating Monte-Carlo simulations," *Phys. Med. Biol.*, vol. 63, no. 20, p. 205013, Oct. 2018, doi: 10/ggjtkb.

[3] M. Del Prete *et al.*, "Personalized 177 Lu-octreotate peptide receptor radionuclide therapy of neuroendocrine tumours: initial results from the P-PRRT trial," *Eur. J. Nucl. Med. Mol. Imaging*, vol. 46, no. 3, pp. 728–742, 2019, doi: 10.1007/s00259-018-4209-7.

[4] M. Del Prete, F.-A. Buteau, and J.-M. Beauregard, "Personalized (177)Lu-octreotate peptide receptor radionuclide therapy of neuroendocrine tumours: a simulation study.," *Eur. J. Nucl. Med. Mol. Imaging*, vol. 44, no. 9, pp. 1490–1500, Aug. 2017, doi: 10.1007/s00259-017-3688-2.

[5] M. Ljungberg and K. Sjogreen Gleisner, "3-D Image-Based Dosimetry in Radionuclide Therapy," *IEEE Trans. Radiat. Plasma Med. Sci.*, vol. 2, no. 6, pp. 527–540, Nov. 2018, doi: 10/gf4465.

[6] M. Ljungberg, A. Celler, M. W. Konijnenberg, K. F. Eckerman, Y. K. Dewaraja, and K. Sjogreen-Gleisner, "MIRD Pamphlet No. 26: Joint EANM/MIRD Guidelines for Quantitative 177Lu SPECT Applied for Dosimetry of Radiopharmaceutical Therapy," *J. Nucl. Med.*, vol. 57, no. 1, pp. 151–162, Jan. 2016, doi: 10/f3mw4b.

[7] E. Hippeläinen, M. Tenhunen, H. Mäenpää, and A. Sohlberg, "Quantitative accuracy of 177Lu SPECT reconstruction using different compensation methods: phantom and patient studies," *EJNMMI Res.*, vol. 6, no. 1, p. 16, Dec. 2016, doi: 10/gf6836.

[8] M. D'Arienzo *et al.*, "Gamma camera calibration and validation for quantitative SPECT imaging with 177Lu," *Appl. Radiat. Isot.*, vol. 112, pp. 156–164, Jun. 2016, doi: 10/gf684q.

[9] M. Chauvin *et al.*, "OpenDose: open access resources for nuclear medicine dosimetry," *J. Nucl. Med.*, p. jnumed.119.240366, Mar. 2020, doi: 10/ggw5t7.

[10] D. Sarrut *et al.*, "A review of the use and potential of the GATE Monte Carlo simulation code for radiation therapy and dosimetry applications," *Med. Phys.*, vol. 41, no. 6Part1, p. 064301, Jun. 2014, doi: 10.1118/1.4871617.